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Optical Technologies for Improving Healthcare in Low-Resource Settings: introduction to the feature issue

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Abstract: This feature issue of *Biomedical Optics Express* presents a cross-section of interesting and emerging work of relevance to optical technologies in low-resource settings. In particular, the technologies described here aim to address challenges to meeting healthcare needs in resource-constrained environments, including in rural and underserved areas. This collection of 18 papers includes papers on both optical system design and image analysis, with applications demonstrated for ex vivo and in vivo use. All together, these works portray the importance of global health research to the scientific community and the role that optics can play in addressing some of the world's most pressing healthcare challenges.

1. Introduction

In view of the rising costs of healthcare and the increasing priority being placed on value-based healthcare, the need for affordable technologies is growing significantly. In addition, pressing healthcare challenges in global health demand biomedical solutions that meet the constraints of low-resource settings; modern challenges caused by the global pandemic also highlight the need for and utility of technologies that can be used at the point of care. Optical technologies have the potential to provide attractive solutions to many of these problems. The rich amount of information available from the interaction of light with the body, coupled with the spectacular advances in and broad applicability of optical technologies that are driving hardware costs down, makes biophotonics a powerful and attractive tool to provide meaningful solutions to critical healthcare challenges, especially in low-resource settings.

2. Summary of contributions

The following summary of the contributions serves to highlight the scope of excellent work included in this feature issue.

2.1. Microscopy

Microscopy still serves as the gold standard platform to diagnose many diseases. Several articles in this issue propose novel methods to construct microscopes that are suitable for low-resource

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settings. The 3D-printed, cost effective and field portable off-axis holographic microscope introduced by Cacace et al [1] is based on the concept of a holographic microfluidic slide. Their detailed discussion of the performance and costs of each parameter, design, and hardware option can help readers implement high-performance systems for testing at the point of care. The OpenFlexure microscope described by Collins et al [2] is a customizable system with a flexible design that has already been tested for educational, scientific and clinical applications in settings like Tanzania and Kenya. Tang et al [3] present a low-cost and user-friendly confocal microendoscope and its in vivo, clinical use to image precancerous lesions in the cervix.

2.2. *Smartphone-based microscopy*

The introduction of smartphone technology presents new opportunities for digital microscopy in a compact form-factor. In Szydlowski et al [4], oil droplets are shown to serve as robust lenses that can enable stable imaging without custom setups, specialized components, or manufacturing processes. Zhu et al [5] also present a smartphone-based microscope that can be used for imaging fresh tissue specimens. Their system costs less than $3,000 and achieves sub-micron resolution over a sample area of nearly 0.5mm. McKay et al [6] demonstrate the power of smartphone optics for non-invasive screening. Using a reverse lens technique and oblique illumination, they demonstrate measurement of optical absorption gaps that may be used for white blood cell screening.

2.3. *In vivo physiological parameters*

Building on this latter work, this issue also features a number of papers that measure various in vivo biometric and physiological parameters. In He et al [7], we are introduced to a technique that uses Weiner estimation to transform pseudo-hyperspectral images acquired with an unmodified smartphone into absorption measurements that mimic the performance of high-cost hyperspectral imaging systems. Nishidate et al [8] measure multiple physiological parameters, including total hemoglobin and tissue oxygen saturation, by using a combination of color-space transformation and Monte Carlo simulation. The new framework for pulse wave extraction presented by Wang et al [9] allows for non-contact estimation of atrial fibrillation, heart rate variability, and blood pressure using a commercial camera. Measures of cognitive decline using portable functional near-infrared spectroscopy are demonstrated by Yu et al [10]. Their findings imply that portable fNIRS devices may be useful for early diagnosis of mild cognitive impairment, a condition associated with increased likelihood of developing Alzheimer's disease. The low-cost and affordable PedCam introduced by Toslak et al [11] provides another example of the ways in which off the shelf optical components can aid in the management of diseases in underserved areas. Their first demonstration of trans-pars-planar illumination enables an ultrawide field of view necessary to facilitate pediatric fundus photography.

2.4. *Machine learning*

Some articles in this feature issue also highlight how recent advances in machine learning can be leveraged to enable low-cost optical technologies to provide compelling solutions to healthcare challenges. The whole slide imaging system described by Rai et al [12] uses deep learning to enable automated focusing of microscopy data that is comparable to the natural ability of human operators. In Haeffele et al [13], a lens-free microscope is augmented by a convolutional neural network trained for platelet detection. This system allows collection of lens-free and fluorescent microscopy images in the same field of view of diluted whole blood samples with fluorescently labeled platelets.

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2.5. Biosensors

Biosensors allow the detection of specific analytes that are useful to detect diseases. The work of Zhu et al [14] shows promising results on the detection of urinary bladder cancer and classification of high grade versus low grade bladder cancers. They demonstrate a fluorometric optical sensor system for the sensitive, real time measurement of volatile organic compounds (VOCs) as biomarkers of urinary bladder cancer. In Cano-Velázquez et al [15], functionalized polydimethylsiloxane enables label-free, real-time immunosensing of antigens for tuberculosis diagnosis. This work speaks to the more general promise of simple optical methods to enable novel analytical tools.

2.6. Infectious disease

Finally, as pertains to global health, we cannot neglect to mention the importance of new technologies that can help control infectious diseases. Lucidi et al [16] introduce a geometric optics-based approach to measure the optical density of bacteria cultures using a low-cost LED photometer. The frugal, easy to manufacture, doped polydimethylsiloxane filtering optical lenses presented by Long et al [17] can be integrated into smartphone microscopes for rapid detection of fluorescently labelled bacteria. Lastly, our editor's pick paper by Goodwin et al [18] describes an interesting optical system that can facilitate mosquito identification that intends to remove the logistical burden of vector surveillance that limits containment.

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Disclosures

The author declares no conflicts of interest.

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